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THE MISSISSIPPI FLOODS.

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THERE has been of late quite a widespread inquiry as to whether or not the climatic conditions of the earth are changing, and whether floods, tornadoes, and other destructive meteorological phenomena are not more frequent in this than in former ages.

As regards temperature, which, to most people, goes far toward constituting climate, the question of secular change can only be indefinitely settled, owing to the fact that exact methods of measuring the temperature of the air were wanting until within the past two centuries.

But as to freshets and inundations there is ample evidence to show the severity and frequency of these destructive phenomena, and the universality of their prevalence is, perhaps, best exemplified in the tradition of a general flood, since this myth is common to almost every nation or people.

Floods and inundations have been very serious matters in Europe for several centuries, and during the past generation the question of their origin, progress, and amelioration has engaged the attention of the ablest European engineers. In what may be called a local way, since the catchment basin of the Seine has an area of less than thirty thousand square miles (less than one-fortieth of the area basin of the Mississippi), the problem has been most clearly stated and settled in France by Belgrand and Chateaublanc. The *reboisement*, or reforestation, of the mountain slopes of southeastern France has done much in modifying the torrents therefrom; while the establishment of more than one hundred gauging and rainfall stations enables forecasts to be made with a fair degree of accuracy as to height, time, and duration.

Even were the geological conditions of the Mississippi basin known as definitely as those of the Seine, yet a similar extension

in the United States of gauging and rainfall stations could not be looked for, since a proportionate number would be over four thousand stations, against one hundred and fifteen at present.

It is only within the past thirty years, as the United States have become more densely populated and the demand for rich and arable ground has correspondingly increased, that the problem in question—that of floods—has received any extended and scientific consideration. The elaborate and valuable work of Humphrey and Abbott on the Mississippi River embodies the first systematic efforts to investigate this question scientifically. This investigation, interrupted by the War of the Rebellion, has only been renewed within the past few years. The most competent engineers of the country have had under consideration the question as to what methods, if any, will mitigate or ameliorate these recurring disasters. The methods to be followed and the damages to be averted involve ultimately hundreds of millions of dollars, and the question is one which cannot be treated cursorily, even by the best engineers of the world. The present writer is in no way an engineer, but in the official line of his duties his attention was brought, some sixteen years since, to the manner in which floods form and to the extent to which inundations occur over areas susceptible to damage by these freshets.

The suggested remedies for the amelioration of flood conditions along the Mississippi River have frequently emanated from persons either superficially informed concerning the problem, or who have failed to grasp its enormous import and to comprehend the vast array of physical data bearing on a question concerning the drainage area of a third of the United States.

The oldest and most strongly-urged plan is the so-called reservoir system—that is, the impounding of the spring freshets near the headwaters of the tributaries, particularly of the upper Mississippi and Missouri rivers, so as to remedy the flood conditions in the lower valley, while at the same time furnishing motive power for industrial purposes or reserving a supply of irrigating water for agricultural purposes. The writer believes that the statements following herein, which are only a résumé of facts, clearly disclose the futility of this method, which has, however, received indorsement in high places.

The present damaging flood renders it, perhaps, a suitable time to present a definite description of some of the characteris-

tic features of the great floods of the Mississippi catchment basin, and to point out some of the fallacies and erroneous opinions which are believed to prevail generally, even among the educated and thoughtful classes of Americans. If this paper serves no other purpose, it is possible that the facts set forth may serve as convincing proof that certain suggested methods for preventing injuries by floods are chimerical and impracticable.

Possibly there is no opinion regarding the causes of floods more general and more firmly fixed in the public mind than that the greater part of the floods of the Mississippi are the result of melting snows near the headwaters of the tributaries in the Rocky Mountain ranges. The general public may be pardoned for this opinion when the idea is gravely and seriously advanced before a congressional committee that the floods of the lower Mississippi can be ameliorated by impounding in artificial basins the waters near the head of the more important tributaries. Still further may the student, even, be misled when so careful and able a writer as Woeikof, in his "*Klima der Erde*," sets forth almost the same opinion. Speaking of the Mississippi, he says:

"The upper river rises under the influence of the melting snow, and the high water which sometimes rises therefrom meets in the lower part of the stream the higher water of the spring rainfalls in the districts of the Ohio, Red, and other rivers."

Let us first examine the question as to what influence, if any, the melting snow exerts on the upper Mississippi and the Missouri.

If the flood water comes from melting snows, it is evident that either the water must reach the rivers during the winter months, which the river stages show is not the case, or the snow must be on the ground at the end of the winter. The following figures show the amount of snow, in inches, at the end of January, February, and March, as deduced from observations for nine consecutive years, over the section of country where the headwaters of the tributaries of the Mississippi are situated:

At the end of January—Dakota, average amounts, from 2 to 13 inches; Colorado, 2 to 7; Montana, 3 to 10; Wyoming, 3 to 4.

At the end of February—Dakota, average amounts, from 1 to 13 inches; Colorado, 3 to 11; Montana, 2 to 8; Wyoming, 1 to 4.

In March, the month when the mean temperatures over these States rise above the freezing-point for the greater part of the day, the snow remaining at the end of the month averages as follows: Dakota, from 1 to 4 inches; Colorado, from 5 to 12;

Montana, from trace to 1 inch; Wyoming, from trace to over 4 inches.

It must not be considered that these figures indicate the presence of snow at the end of either January, February, or March over the entire area of these States. It is an exception when the greater part of the territory is covered with snow for any considerable number of days. As a rule, snow disappears over the greater part of the Rocky Mountain region nearly as rapidly as it falls. The considerable amount of snow (5 to 12 inches) noted in Colorado, the most southerly of the States named, depends on the fact that the observations include measurements made on Pike's Peak summit and at other elevated stations in the mountain regions, where the snowfall is heaviest and whence the floods are supposed to proceed. But even there at the end of March the amount of snow, if melted all at once, would barely equal an inch of water.

"If, then, the snow does not melt and flow into the streams, what becomes of it?" some person will ask. This question is easily answered by any one who has lived in either of the States named, and who has noticed the rapidity with which the dry, cold air, even when far below the freezing-point, absorbs by evaporation the small amount of snow as it falls.

Save in a very few localities, the snowfalls of the Rocky Mountain region are comparatively trivial. The entire amount of snow which annually falls in Nebraska and Wyoming varies, on the average, from one to two feet; and in Dakota and Montana from one and a half to two and a half feet. This is based on the supposition that the entire precipitation from December to February inclusive is in the form of snow, which is not strictly true; so that the average amount of snow for the whole of the Rocky Mountain region does not exceed one and a half feet annually.

The little influence exerted by snowfalls upon the upper Mississippi and the Missouri rivers is shown by the fact that at St. Paul the Mississippi, usually frozen until about March 20, remains until that time at or near its lowest stage for the year—three feet or less above the lowest water ever known. The Mississippi at that point is frequently closed until the early part of April, and during the few days when the river is open in March—which occurs in connection with rains—the river rises only about five feet above extreme low water. As far south as

Yankton, on the Missouri, that river remains frozen up, as a rule, until the middle of March, and during the latter part of that month, even taking into account occasional high water caused by ice gorges, the average stage of the river is less than a foot and a half above the lowest monthly stage—in December—and is not quite six feet above extreme low water.

The flood water, then, of the upper Mississippi and the Missouri rivers comes from the heavy rainfalls during the months of April, May, and June, especially during the last two months, when the entire upper Mississippi valley and the lower portion of the Missouri valley have average rainfalls ranging from four to seven inches in depth, which would be equal for the whole of these regions to about five feet of snow on the level. The heavy rainfall in the lower Missouri valley during March shows its effect immediately on the St. Louis gauge, the river rising slowly from 10.0 in January, to 12.4 in February, and 17.1 feet in March, which latter point, however, is 13 feet below the freshet line.

It is now necessary, for a proper elucidation of the subject, to note clearly what portion of the entire Mississippi catchment basin is subject to floods, and whether these inundations are periodical or accidental; meaning by these terms that inundations are periodical when they recur almost annually, while those caused by extraordinary meteorological conditions are accidental.

There is no fairer test by which to estimate the flood stage of a river than by determining the level at which the water injures material interests extensively. This point, technically known to the Signal Service as the "danger-line," was fixed by the writer in 1874 for the Mississippi and its tributaries. In examining the records for periods ranging, according to the station, from eight to nineteen years, it is evident that floods in the whole Missouri valley and in the upper Mississippi valley, as far south as St. Louis, are accidental. At St. Louis the average number of days of flood water annually is but three. At Omaha flood conditions obtain about seven days a year on the average.

The valleys of the Tennessee and the Arkansas are subject to floods which may also be called accidental, since they only occur one year in three, with an average annual number of three flood days at Chattanooga, Tenn., and five at Little Rock, Ark.

The valleys of the Cumberland and of the Red River present debatable conditions, since at Nashville, Tenn., and Shreveport,

La., floods occur every other year, and the water remains above the danger-line, on an average, eight or nine days annually.

The Ohio, except near its mouth, is also doubtful ground, since flood water occurs for a week or more at Cincinnati every other year, and every third year prevails for more than two weeks.

This, then, confines the periodical floods, which recur three years out of every four, to the Ohio below Louisville and the Mississippi from Cairo to the Gulf, while the maximum flood phases obtain in the central Mississippi valley from Helena to Red River.

It is now important to determine closely and accurately the time of the year when floods occur; and in so doing one naturally treats them in sequence of time, since, fortunately, the accidental floods, as well as the highest river stage in non-flood years, fall for the upper Mississippi and the Missouri rivers long after the crest of the flood wave has passed down the lower Mississippi.

The Arkansas freshet, one of the earlier, is a double wave, the maximum of February being often followed by a second rise in May. The February rise comes from the heavy rains in the lower valley, and is rarely prolonged late enough to seriously affect the Mississippi flood, while the May rise, augmented by the outflow from the central and upper Arkansas valley, only serves to check the slowly-receding Mississippi.

In the Cumberland, Ohio, and Tennessee the annual flood, as shown by the mean stage of these rivers for many years, comes in February. This annual freshet results from the heavy spring rains in Tennessee and the Ohio valley. The bulk of the crest of this wave passes Cairo into the Mississippi in late March and early April, being supplemented by the February freshet of the Arkansas and the March flood of the Red River. The Mississippi has its highest stage in March, except between Helena and Red River Landing, where in severe flood years, such as 1862, 1882, and 1890, it has its highest water during April. This peculiarity is due to the overflow (above Helena on the west and Vicksburg on the east side) into the St. Francis, Yazoo, and other smaller basins, which water returns to the main river, from Helena southward, in time to again swell the slowly-falling flood of March.

The figures and measurements regarding the relations of river outflow to rainfall, on which the whole question of floods eventually turns, have been drawn from a very valuable and full report upon this subject made by Professor Thomas Russell, of the

Signal Service, which forms a part of the annual report of the Chief Signal Officer for 1889. The river outflows were taken by Professor Russell from the measurements and calculations made by and under the supervision of the Mississippi and Missouri river commissions. The work done by these commissions has been of the highest possible character, and the results may be depended upon as being the most accurate possible, the outflow probably being in error not exceeding 5 per cent.

Let us examine the greatest of the Mississippi floods prior to the one from which the lower valley is now suffering—the flood of 1882. It is found by analysis that of the water which during the entire year 1882 passed Red River Landing 11.6 per cent. came from the upper Mississippi valley (that is, above the mouth of the Missouri), 19.5 per cent. from the Missouri valley, 33.5 per cent. from the Ohio valley, and 35.4 per cent. from the valley of the lower Mississippi, including the outflow from the Arkansas and Red rivers. But the great flood of the lower Mississippi came in 1882, as in this year, during the months of February and March, so that it is more strictly in order to consider the amounts of river outflow during January, February, and March of that year (1882). We find that from the Missouri valley above the mouth of the Platte the outflow amounted to 2.18 cubic miles during these three months, and from the valley below to 1.50 cubic miles, making for the entire Missouri valley 3.68 cubic miles—an amount which we shall see is inconsiderable as regards the discharge from the Ohio and the amount contributed by the lower Mississippi valley. The upper Mississippi valley contributed during this time 6.56 cubic miles, making for these two great valleys 10.24 cubic miles. During the same time the Ohio valley gave an outflow aggregating 50.48 cubic miles, or five times the amount which flowed from the valleys just named.

To prove clearly the unimportance of the Missouri and upper Mississippi rivers in connection with the great floods of the central and lower Mississippi valleys, the following data relative to the great floods of 1874, 1882, and the present year are important:

In the case of the great flood of 1874 the Missouri and upper Mississippi rivers remained at or below their average stage until June, thus contributing a small and unimportant amount of water to the flood stages of the lower Mississippi during April.

In 1882 the flood periods (that is, the periods during which the lower Mississippi was above the danger-line) were as follows : At Cairo, from January 13 to April 4, eighty-one days; Memphis, from January 24 to March 30, sixty-five days; Helena, from January 1 to April 23, one hundred and fifteen days; Vicksburg, from January 22 to July 2, one hundred and sixty-two days; New Orleans, from February 11 to May 12, ninety-two days; and Paducah, Ky., from January 16 to March 20, sixty-four days.

This indicates that the flood period of the lower Mississippi ran from the middle of January to about the 1st of April at Paducah, Ky., and Cairo, at the northern end of the river; and from the middle of February until about the middle of May at New Orleans, in the lower portion of the river. It is evident, then, that any flood water to aggravate the period must have passed Cairo by the 1st of April, 1882. The Mississippi, however, was frozen at St. Paul until the 27th of March; the Missouri, frozen at Yankton until the 14th of March, remained about four feet below the average stage until early in May both at that point and at Omaha.

The flood water in that year came from the following directions : from the Cumberland, as shown by twenty-two consecutive flood days, January 11 to February 2, at Nashville; from the Tennessee, as shown by nine flood days during January at Chattanooga; from the upper Ohio, as shown by twenty-eight flood days, scattered through the months of January, February, and March, at Cincinnati, with water at a very high stage for the remaining sixty-two days of the period. The Arkansas was not a serious factor in the problem, as only six flood days in February prevailed at Little Rock, but the heavy local rains in the St. Francis bottom and the Yazoo basin coincided with the enormous floods flowing from the Ohio River, thus serving not only to prolong the flood between Memphis and Red River Landing, but also to actually increase it. For the valley of the Mississippi below the Red River the situation was aggravated by a serious flood from the Red River, as shown by thirty-three freshet days at Shreveport from the 16th of February to the 19th of March, 1882.

In reviewing the floods of the present year, it is equally apparent that the Missouri and upper Mississippi rivers did not produce the existing flood conditions. The Mississippi River was frozen at St. Paul at the end of March, and at Davenport, Ia., as

late as the 15th of March. At the end of the month the upper Missouri was also frozen, and, as far as is known, the river everywhere showed a very low stage. The outflow of these rivers is, however, definitely fixed by the stage of the river at St. Louis, which during March, 1890, was about seven feet below the average stage for the month. The Arkansas at Little Rock has not risen to flood stage, nor has the Red River at Shreveport. In short, the flood is due to the freshets from the Ohio and its important tributaries, the Cumberland and the Tennessee, with superadded rainfalls in the central Mississippi valley.

The first flood days at Cairo in January, while largely due to rainfall in the catchment basin of the Ohio, came, however, from precipitation in unexpected localities, the southern parts of Illinois, Indiana, and extreme southern Missouri, where the rainfall was the greatest ever known for January, exceeding ten inches at eight stations covering a large area of country.

These unusual conditions caused the lower Ohio and the Mississippi to rise above or to the danger-line, and just as the effects were passing away the usual freshets set in by the middle of February in the upper Ohio, and near the end of the month for the Cumberland and Tennessee. During February the precipitation in the Ohio valley was somewhat in excess of the average; yet it was about 10 per cent. less than the rainfall of the flood month of February, 1882. During March, however, the rainfall has been excessive over the catchment basin of the Ohio valley as a whole; at least twenty-four cubic miles of rain has fallen, which is nearly 50 per cent. greater than the amount which fell in 1882. Fortunately, this great excess was somewhat offset by the rainfall in the upper Mississippi valley being about 2.25 cubic miles less than for March, 1882; while the rainfall for the lower Mississippi, from Helena southward, was deficient to the extent of about an inch at Vicksburg, increasing to a deficiency of over eleven inches at New Orleans for January, February, and March.

The total rainfall in the Ohio and upper Mississippi valleys during January, February, and March, 1882, aggregated eighty cubic miles of water; during the corresponding months in this year, to seventy-nine cubic miles. In 1890 the excess during March was five cubic miles over that for March, 1882; so that flood conditions may be expected to last later than in that year.

But some one will say : " If the 3.68 cubic miles for the Missouri and the 6.56 for the upper Mississippi valley, during January, February, and March, 1882, had been impounded, the floods would not have occurred." That this is not the case is shown by the discharge at Columbus, Ky., which in the first three months of 1882 was as follows : January, 21.87 ; February, 23.02 ; March, 22.92 cubic miles ; aggregating 67.81 cubic miles. We find, moreover, by the measurements at Hayes's Landing, near Vicksburg, Miss., that the discharges during the three months named were : January, 16.76 ; February, 15.96 ; March, 17.42 ; amounting to only 50.14 cubic miles. But it is to be borne in mind that the distance from Columbus to Hayes's Landing is about three hundred and fifty miles, and that it is not strictly accurate to compare the outflows for identically the same days, owing to the slow progress of the freshet wave down the Mississippi. Allowing for the movement of the freshet wave, the discharge at Hayes's Landing from January 6 to April 6 was found to be almost identical with that for the even months. It appears, then, that 17.67 cubic miles less water passed Hayes's Landing, Miss., during the months of January, February, and March, 1882, than passed the gauge at Columbus, Ky. This amount must again be increased by part of the rainfall and river outflow between Columbus and Hayes's Landing.

The additional drainage area between Columbus, Ky., and Hayes's Landing, Miss., comprises 71,000 square miles, over which the rainfall in 1882 was as follows : January, 7.64 cubic miles ; February, 10.48 ; March, 3.40 ; aggregating 21.52 cubic miles.

As only 30 per cent. of the rainfall in this area became river outflow, it is then evident that (neglecting the small amount of rainfall in the Yazoo basin) during the three months mentioned 23.87 cubic miles of water passed over the levees between Columbus, Ky., and Hayes's Landing, Miss., reaching the river at Vicksburg through the Yazoo bottom, or the Red River by the Tensas basin. During this period the water passing Hayes's Landing, Miss., amounted to 50.14 cubic miles. In other words, the Mississippi River channel bank-full at that point from January to March, inclusive, in 1882, was able to carry off less than 70 per cent. of the water flowing from above.

This fact brings out in bold relief the first and most important problem to be solved—that is, to increase the carrying capac-

ity of the Mississippi River at and north of Hayes's Landing 46 per cent. above what it was in 1882. Outlets at Lake Borgne and by the Atchafalaya may or may not relieve the river below the Red River. The most zealous advocates of these outlets will hardly claim such an effect on the river above Vicksburg.

It is not reasonable to assume that any supporter of the impounding theory would maintain the possibility of storing up any considerable water during the winter months, when the headwaters of the Mississippi and Missouri are frozen; but if we allow that half the amount flowing through these rivers during January, February, and March could be diverted into reservoirs, it would reduce the water passing Columbus by 5.12 cubic miles. This reduction, however, would not have any material effect upon the conditions at Columbus, since we find that, deducting the 5.12 cubic miles from the Missouri and upper Mississippi valley, there are yet 18.75 cubic miles of water which failed to reach Hayes's Landing, but inundated the entire alluvial grounds in the Yazoo bottom and from the St. Francis to the lower part of the Tensas basin.

In order, then, to reduce the volume of the Mississippi so that the discharge of flood waters at Columbus should just equal the quantity passing Hayes's Landing in 1882, and thus stop all overflow and inundation between these points, it would be necessary to impound not only 50 per cent. of the water from the Missouri and upper Mississippi, but also 18.75 cubic miles of water from the Ohio. The amount from the Ohio alone would cover an area of 19,000 square miles—half the area of Kentucky—to the depth of five feet. A reservoir or a series of reservoirs capable of containing this amount of water is impracticable; and if otherwise, no doubt exists that the presence of such enormous reservoirs would be a standing menace to the public safety at one season, and, more important, to the public health during the greater portion of the year when flood conditions do not obtain.

In short, it appears evident from the above figures, if calculations of this kind can be depended upon,—and every one must admit that engineering problems are based on calculations of this character,—that the impounding of waters by reservoirs is entirely out of the question as regards the Missouri, the upper Mississippi, and the Ohio rivers.

The writer sums up here the points which he has endeavored to make clear : (1) that the freshets of the Mississippi River and its important tributaries are not due to the melting of winter snows; (2) that since the upper Mississippi valley freshet occurs as late as April and the floods of the Missouri occur in June and July, and, further, as both of these rivers are at a low stage during February and March, they cannot and do not materially contribute to the floods of the lower Mississippi, which occur in late March and early April; (3) that if all the water in the upper Mississippi and lower Missouri rivers was impounded, leaving St. Louis a city on a dry creek, the floods on the lower Mississippi River would none the less continue; (4) that the floods in the central Mississippi valley, between Cairo and Red River Landing, could not be materially ameliorated by increasing the number of outlets into the Gulf below Red River Landing, since, as the outflow measurements show, the Mississippi River is unable to carry bank-full the flood which pours by Vicksburg in freshet years; (5) that the floods in the Mississippi valley below the mouth of the Red River are, in a measure, distinctive floods, and that their treatment must be individual, as they are somewhat independent of the central Mississippi valley, where the flood periods are much prolonged beyond their prevalence in the delta region. In fact, any method which increases the flow of the river or the rapid discharge of water from the Mississippi valley above Vicksburg must inure to the disadvantage of the delta country. On the other hand, the augmenting of the flow of water in the delta country can only incidentally and slightly ameliorate the flood conditions of the central Mississippi region.

As regards the delta country, in years of severe flood it always receives from the Red and the Mississippi more water than the river channel can carry. During the flood months of 1882 the river outflows at Red River Landing and Carrollton, respectively, were as follows : March, 25.53 and 16.42 cubic miles ; April, 24.69 and 15.34 ; May, 21.54 and 14.80 cubic miles. In other words, to allow all the flood waters of 1882 to pass New Orleans would have required an increase of 54 per cent. in the river outflow at that point. This excludes 10.94 cubic miles of discharge through the Atchafalaya ; but if half of this were forced into the Mississippi, it would necessitate an increase of 66 per cent. at Carrollton over the discharge of 1882.

Another point of interest is the question whether the floods are increasing in frequency and severity. Cincinnati, Cairo, and Helena appear to answer this question in the affirmative ; but it should be remembered that the levee system might cause a seeming rise at the latter two places. It is problematical whether such a change alone has increased the number of flood days at Cairo from an average of twenty-two in the ten years from 1871 to 1880 to more than forty days for the ten years 1880 to 1890, and at Helena from forty-nine to seventy days for corresponding periods. At Cincinnati, however, the river, while changed in thirty years, has not been restrained by levees, so that flood conditions are less affected by physical modifications of the local terrain. It seems possible, if not probable, that the increase of flood days at Cincinnati from seven days for seventeen years, from 1858 to 1874, to eleven days from 1874 to 1890, is not accidental, but, rather, due to changed physical conditions. The meteorological record at Portsmouth, in the Ohio valley above Cincinnati, indicates that the average rainfall for the first period, 1858 to 1874, is substantially the same as from 1874 to 1890. As this article is intended to avoid theories and hold fast to facts, the question of causes will not be here pursued.

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